INTENSITY OF PRECIPITATION.

The intensity, or rate, of rainfall varies from zero up to several inches per hour, and, like the strength of the wind, has been popularly divided into several, more or less definite, grades. Most of these, together with the roughly averaged values they imply, are given in the accompanying table.

Precipitation values.

Popular name.	Precipitation intensity, mm. per hour.	Milligrams liquid water per liter of air.	Velocity of fall, meters per second.	Height of cloud, meters above surface.
Clear	0.00	0.00		
Fog	Trace.	0.60	0.003	0
Mist	0.05	5.55	0.25	100
Drizzle	0.25	9.26	0.75	200
Light rain	1.00	13.89	2.00	600
Moderate rain	4.00	27.78	4.00	600
Heavy rain	15.00	83.33	5.00	1,000
Excessive rain	40.00	185.19	6.00	1,200
Cloud-burst	100.00	540.14	7.00	1,200

—*W. J. Humphreys.*

THE WATER CONTENTS OF THE ATMOSPHERE IN RELATION TO HEAVY RAINFALLS.

W. H. Dines has published in the October, 1918, number of the Symons's Meteorological Magazine, a summary of the usual water contents of the atmosphere in western Europe, as determined by the humidity records of 250 registering balloons.

Mr. Dines says:

In the winter the total equivalent rainfall is about 0.40 in., with a range from 0.25 in. to 0.80 in.; in summer the mean is about 0.80 in., with a range from 0.50 in. to 1.50 in. The amount seems to depend chiefly on the temperature and but little on anything else, i. e., if the air is warm there is almost certain to be plenty of moisture and conversely. Practically all the water is contained in the first few kilometers.

These amounts, which would be precipitated if all the moisture present in the atmosphere over a place were condensed, are small relative to those which might result from the inflow of moisture which occurs in the usual convergence of winds in a cyclone. Taking as an example a circular area of 100 kilometers radius, a wind 500 meters deep and having an inflowing component of 10 meters per second would bring in the course of 24 hours sufficient moisture to produce about 8.6 inches (220 mm.) if the temperature were 80° F., 6.6 inches (160 mm.) at 70° F., 3.2 inches (80 mm.) at 50° F., and 1.5 inches (40 mm.) at 30° F. If the circular area were 100 miles in radius and if the inflowing component of the wind were 10 miles per hour, these values would be about quartered. The actual rainfalls would be less, for some of the moisture remains when the air flows away from the area aloft. If the air should be cooled 30° F., as it would in ascending about 2 miles, the precipitation would be about a third less. Since the air which goes into a cyclone does not rise uniformly about the center, the rainfall rate may easily be doubled over considerable areas, at the expense of that over other areas. If a cyclone, however, is moving, this difference in rate might not show in the distribution of total rainfall.—*C. F. B.*

PANAMA THUNDERSTORMS.

By H. G. CORNTHWAITE, Asst. Chief Hydrographer.

[Dated: Balboa Heights, C. Z., October, 8, 1919.]

SYNOPSIS: Thunderstorms in Panama are of frequent occurrence during the eight rainy-season months. More occur over the interior than along either coast, and generally more occur in the afternoon than during the night or early morning.

Thunderstorms are more numerous in Panama than anywhere in the United States, averaging from 100 to 140 per year, but the total loss of life and property damage is relatively less in Panama than in many sections of the United States, probably due to (1) electric discharges between clouds, failing to reach the earth, (2) numerous uninhabited hilltops serving as conductors and protecting the inhabited valleys, and (3) atmospheric conditions favorable for ready interchange of electric currents, tending to prevent the accumulation of powerful electric stresses or differences of potential.

INTRODUCTION.

Thunderstorms are of frequent occurrence in most tropical and equatorial regions of heavy rainfalls. In Panama the curves of thunderstorm frequency follow fairly closely the curves of average monthly rainfall, but August is generally the month of maximum thunderstorm frequency while May and November are the months of heaviest rainfall. There is a marked decrease in thunderstorms in November and December due to a decrease in the number of afternoon convective showers, yet November is usually the *rainiest* month of the year.

The following table shows the yearly average number of thunderstorm days at stations in the Canal Zone, compared with selected stations in the United States:

Station.	Location.	Approximate elevation.	Years of record.	Thunderstorm days each year.
		Feet.		
Colon	Atlantic coast	10	11	106
Culebra	Continental Divide	400	7	137
Balboa Heights	Pacific coast	100	13	119
Tampa, Fla	Gulf coast	67	10	94
Santa Fe, N. Mex	Rocky Mountains	7,013	10	73
Chicago, Ill	Great Lakes	595	10	40
New York City	Atlantic coast	314	10	28
San Francisco	Pacific coast	155	10	1

From an inspection of the accompanying fig. 4 it will be seen that Panama thunderstorms are most numerous in the interior near the Continental Divide and fewest along the Atlantic coast.

HOURLY DISTRIBUTION OF THUNDERSTORMS.

Sufficient data are not available to show accurately the curves of hourly distribution of thunderstorms in Panama, but in a general way from 75 per cent to 80 per cent of all thunderstorms occur in the daytime on the Pacific coast and over the interior, while along the Atlantic coast nearly half of the thunderstorms occur during the night or early morning. The reason for this difference in thunderstorm distribution is to be found in the character of prevailing rainstorms. On the Pacific coast and over the interior most of the rains are afternoon local showers of convective origin, usually accompanied by thunder and lightning, while along the Atlantic coast the climate more closely resembles the marine type and much of the rainfall comes in the form of general storms of wider extent,

[To face p. 723.]

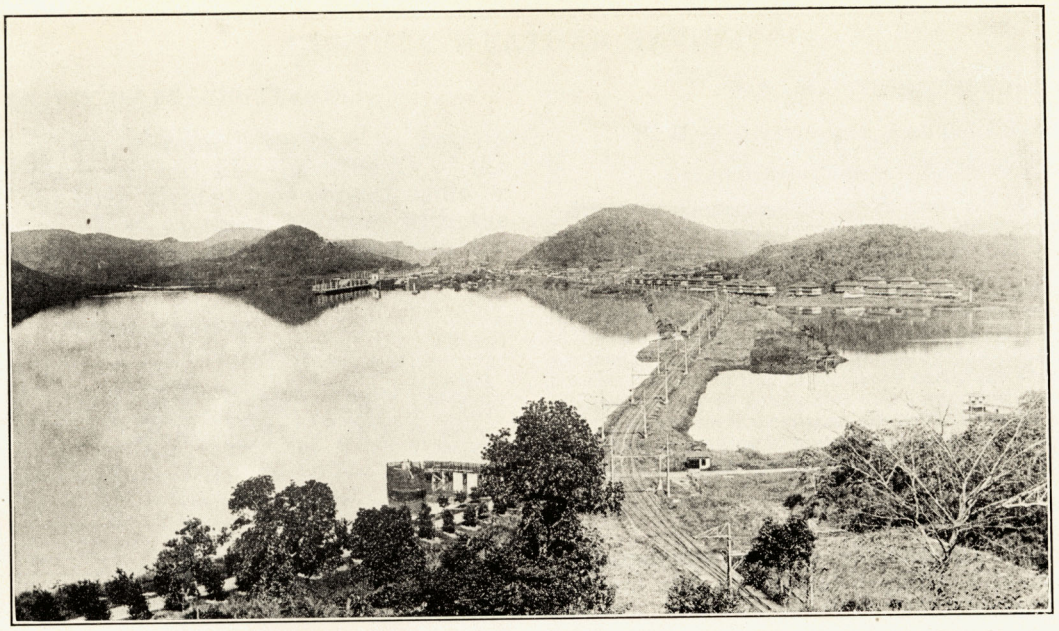

FIG. 1.—Hilly topography surrounding Miraflores Lake. Typical Canal Zone topography. (Photo by H. G. Cornthwaite.)

FIG. 2.—Rainstorm sweeping across Gatun Lake. Note the decaying jungle forest partly submerged in Gatun Lake. The forest died quickly when the lake was filled. (Photo by H. G. Cornthwaite.)

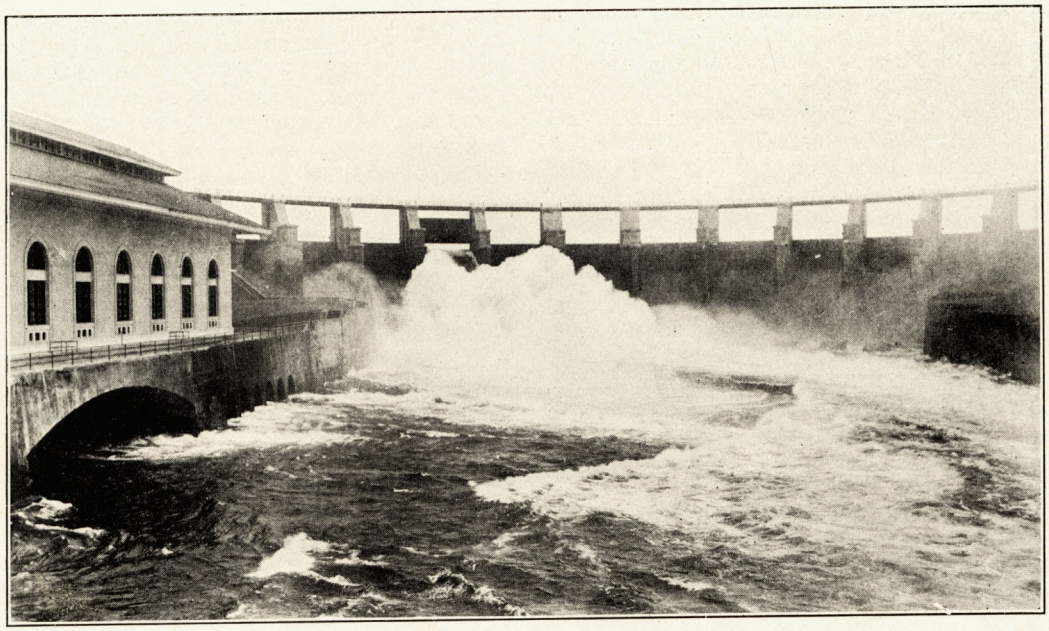

FIG. 3.—Flood waters from excessive rains discharging through the spillway at Gatun. At times the flood discharge into Gatun Lake exceeds the rate of 100,000 c. f. s. View shows 12,000 c. f. s. discharging. (Photo by H. G. Cornthwaite).

many of which occur during the night or early morning. In the Tropics night and early-morning thunderstorms seem to prevail over *ocean areas* and afternoon thunderstorms predominate over *land areas*.

ATTENDANT PHENOMENA.

Precipitation.—Practically all Panama thunderstorms are accompanied by rainfall, many of the rains being at an excessive rate. The average number of excessive rains per year is about 60 on the Atlantic coast and about 30 on the Pacific coast. Most of these excessive rains accompany thunderstorms, but not all thunderstorms are accompanied by excessive rainfall. (Excessive rains are classified in accordance with the United States Weather Bureau scale of excessive precipitation.) See figures 2 and 3.

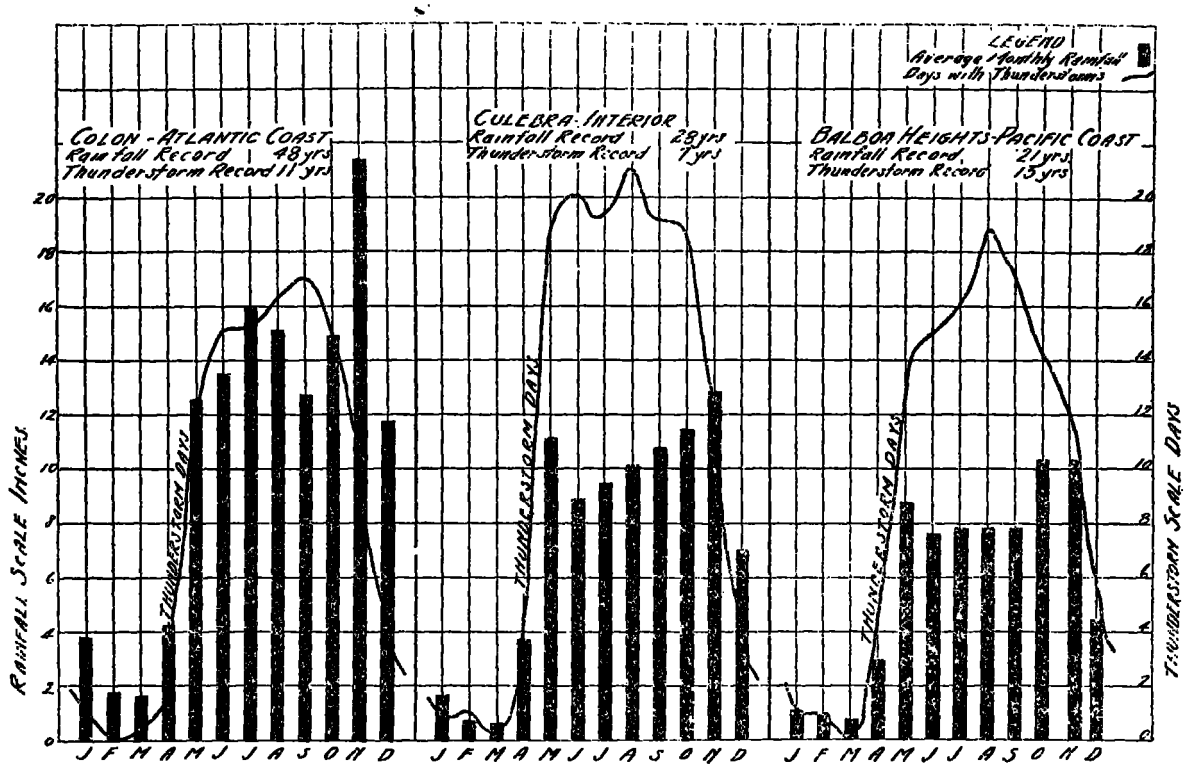

FIG. 4.—Average number of days with thunderstorms compared with average monthly rainfall at Canal Zone stations.

Wind squalls.—Thunderstorms in the Canal Zone frequently are accompanied by wind squalls. These usually have a moderate gyratory motion, but the strongest wind is a straight blow or outrush of air. The wind may blow from any direction. Maximum wind velocities range from 25 up to 45 or 50 miles an hour. These windstorms seldom are of sufficient violence to do much damage on land, and they never are of long enough duration to kick up a heavy sea at either Canal entrance.

Thunderstorms and wind squalls usually travel across the Isthmus from the Atlantic coast toward the Pacific approximately in the direction of the general air circulation, which is from the north or northeast toward the south or southwest. Occasional thunderstorms have been observed to travel in the opposite direction, from the south or southeast toward the north or northwest. Two of the severest windstorms of record in Panama moved across the Isthmus from the southeast. One occurred on July 10, 1909, with a maximum wind velocity of 59 miles an hour from the south at Ancon, and the other occurred during the night of June 16–17, 1919, the maximum velocity recorded being 50 miles an hour from the south at Gatun.

Hail.—Hail has been observed in the Canal Zone or vicinity on three occasions during the past 12 years, accompanying thunder or rain storms. Hail fell at Cucuracha (near Culebra) in 1908, the exact date being unknown, and again at Alhajuela on the afternoon of May 28, 1910. A third hailstorm occurred on Naos Island on June 15, 1912, during a heavy rainstorm. The hailstones that fell during these storms were small and melted quickly, and in no case was the fall excessive. This phenomenon is unusual in a low-lying tropical country, but severe hailstorms are experienced frequently at high altitudes in mountainous regions in the Tropics.

Severe thunderstorms.—Although thunderstorms are very numerous in Panama, averaging from 100 to 140 per year, very few of these storms are particularly severe. Perhaps not more than two or three extremely severe thunderstorms will occur during the course of a year. Contrary to the popular belief that thunderstorms in equatorial regions are something terrific, it is the writer's observation that thunderstorms in the central and upper Mississippi Valley sections of the United States, while not nearly so numerous as thunderstorms in Panama, are frequently more severe and destructive.

LIGHTNING DAMAGE.

Lightning accompanying thunderstorms has caused little damage or loss of life in the Canal Zone and vicinity during recent years. The following table shows the number of deaths by lightning since 1906, taken from the

Health Department vital statistics and from newspaper reports:

Year.	Deaths from lightning.	Year.	Deaths from lightning.
1906		1914	1
1907		1915	
1908	[1] 2	1916	
1909	1	1917	
1910		1918	1
1911	3	Total (13 years)	8
1912			
1913			

[1] Deaths from dynamite explosion set off by lightning.

The average population of the Canal Zone (including Panama City and Colon) during this period was about 120,000.

There are few records of serious property damage from lightning in the Canal Zone. An oil tank at Mount Hope belonging to the Union Oil Co. was struck by lightning on May 20, 1906, and 11,000 barrels of oil were burned. The Colon Radio towers were struck by lightning three times on the night of October 14, 1914, and badly damaged. The instrument tower at Balboa Heights was struck on October 19, 1914. The radio towers are struck by lightning frequently during electrical storms, but when properly grounded they ordinarily suffer little or no damage. Canal lighthouses and range lights have been struck by lightning a number of times. Lighthouse tower No. 5 at the Pacific entrance was struck twice in June, 1918, and badly damaged; and a tall lighthouse tower at Gatun was struck and damaged in August, 1918. An observation balloon at the Coco Solo Naval Air Station was burned by lightning during an electric storm on August 5, 1919. The mess hall located close by was struck at practically the same time and slightly damaged. It was stated in the report of the naval committee that investigated the damage, "That the electric current seemed to pass from the bottom of the building upward and out through the roof." A similar phenomenon was reported a few months earlier on Bona Island out in Panama Bay, where the reinforced concrete lighthouse tower was struck by lightning, the charge seeming to pass from the base of the tower upward and out into space.

The relatively slight damage from lightning suffered in the Canal Zone and vicinity may be partly explained as follows:

(1) A large percentage of the lightning bolts probably never reach the earth, but merely pass from one cloud to another.

(2) In the Canal Zone and vicinity there are a large number of hills with round, conical tops, ranging in elevation from a few hundred feet up to 1,000 feet or more. These hilltops probably serve as lightning rods or conductors, and, being for the most part uninhabited, lightning bolts that strike them do no damage.

(3) It is probable, also, that the humid atmospheric conditions and frequent rainstorms that prevail on the Isthmus and the moist condition of the soil facilitate the ready interchange of electrical currents between the atmosphere and the earth, thus tending to prevent the *accumulation* of powerful electric stresses, or differences of potential, that would finally find relief in *severe* thunderstorms. This is thought to be one of the *principal causes* of the relatively slight damage suffered in the Canal Zone from electric storms.

COMPARISONS.

It is interesting to compare thunderstorm conditions in Panama with conditions in the United States. There are two areas of maximum thunderstorm frequency in the United States. The principal one extends over the Gulf States with center near Tampa, Fla., where the average annual number of thunderstorms is about 94. Another thunderstorm region centers over New Mexico, where the average annual number of thunderstorms is about 73. The Pacific Coast of the United States is the freest from electrical storms. The average number of thunderstorms at San Francisco is *less than one per year.*

Thunderstorms over the central and upper Mississippi Valley States average about 40 per year. A large percentage of these accompany general cyclonic storms, and they may occur either during the daytime or at night. The greatest damage from lightning occurs in the region from the central Mississippi Valley eastward to the Atlantic coast.

Based on the data available it is estimated that from 500 to 1,000 buildings are struck by lightning and burned in the United States each year, and that about 800 people are killed by lightning annually, and many more injured, the average annual death rate from lightning in the United States being approximately one per 120,000 population.

It would seem that although thunderstorms are more numerous in Panama than anywhere in the United States, the total loss of life and property damage from electric storms is relatively less in Panama than in many sections of the United States.

The data on United States thunderstorms presented above were abstracted from papers on thunderstorms, by W. H. Alexander, of the United States Bureau, and Robert DeC. Ward, published in the Proceedings of the Second Pan-American Scientific Congress, Vol. II.